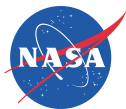


Microwave remote sensing of rain-on-snow events in the subarctic with AMSR2 & GPM observations

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Collaborators: N. Maynard, A. Langlois, S. Mathiesen, I.M. Eira, A. Oskal



International Centre
for Reindeer Husbandry

Context about rain-on-snow events

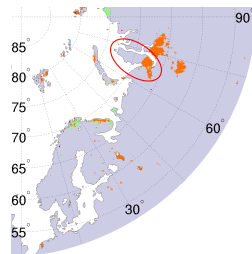
(IPCC 2013)

“The rapid rate at which climate is changing in the Polar Regions will impact natural and social systems.”

“More frequent rain-on-snow events caused by warmer winters may restrict access to vegetation and may have profound negative influences on the population dynamics of Arctic ungulates.”

Web of Science: 135 articles on rain on snow since 1985,
40% published since 2010

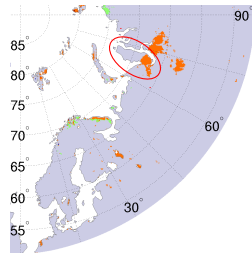
Context about rain-on-snow events



AMSR2 detection
on Nov. 8

Context about rain-on-snow events

Last winter, $\sim 100,000$ reindeer died on the Yamal Peninsula, because they could not break through the ice to graze.



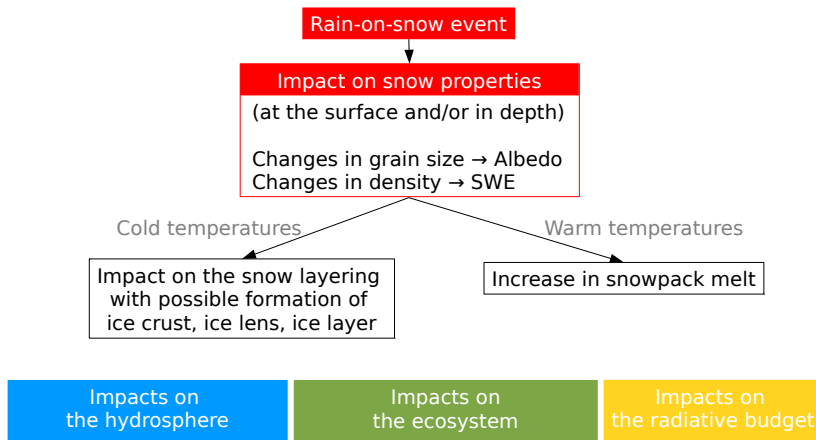
AMS2 detection
on Nov. 8

Why monitor rain-on-snow events?

Relevant for:

- Climate adaptation to improve decision-making (e.g. herd management)
- Wintertime climate change monitoring
- Increasing our knowledge of their impacts

Why monitor rain-on-snow events?



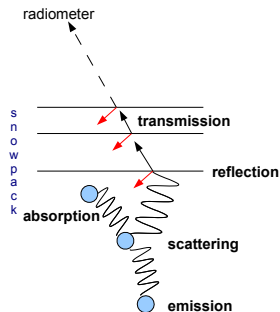
Question: Can we detect rain-on-snow events from microwave satellite observations, *especially* events leading to the formation of an ice layer?

Outline

1. Microwave emission simulations with DMRT-ML
2. A prototype algorithm to detect rain on snow with AMSR-E/2
3. GPM active/passive microwave observations
4. Conclusion

DMRT-ML – Elements

Dense Media Radiative Transfer - Multi Layers model



DMRT-ML computes:

- . emission
- . scattering
- . absorption

} **using the DMRT theory**

DMRT-ML computes the reflection coefficients at:

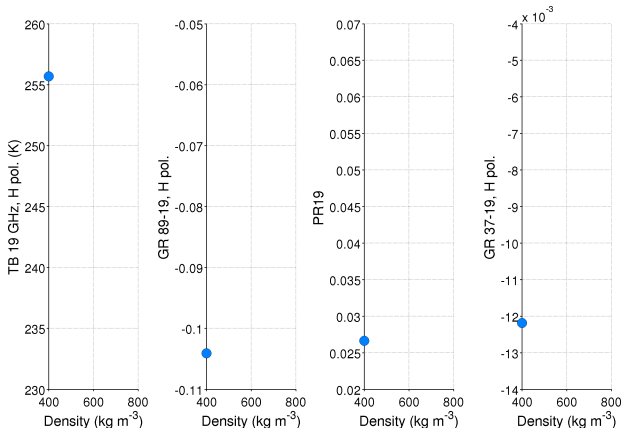
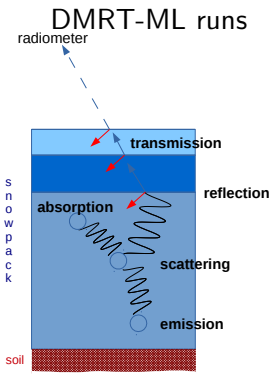
- . snow/snow interfaces
- . snow/atmosphere interface

} **using Fresnel**

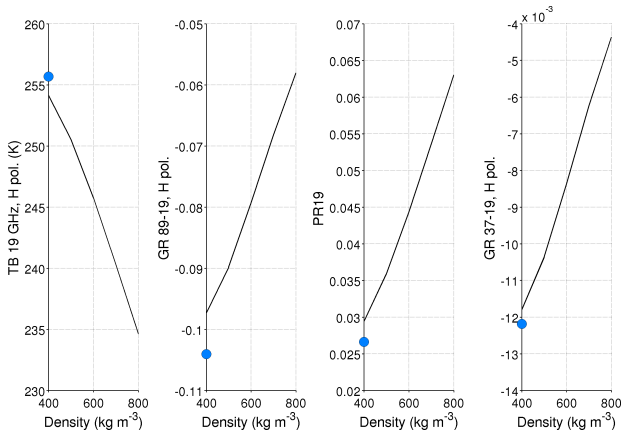
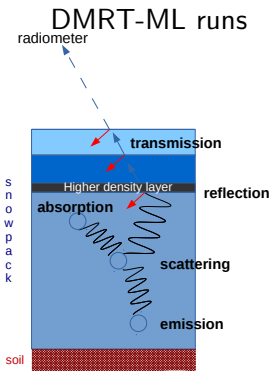
DMRT-ML solves the radiative transfer equation
using the DISORT method

Picard, Brucker, Roy, Dupont, Fily, Royer, Harlow, Simulation of the microwave emission of multi-layered snowpacks using the DMRT theory: the DMRT-ML model. Geosci. Model Dev., 2013

Simulated response to the formation of an ice layer on TB



Simulated response to the formation of an ice layer on TB



Modeling shows that the selected variables respond to an increase in density
 The vertical position of the denser layer matters (*Montpetit et al., TGRS 2013*)

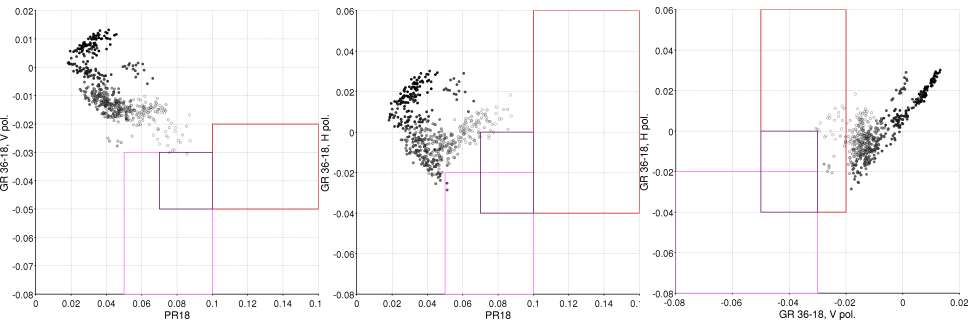
Prototype algorithm

A **prototype** algorithm was developed:

- It uses frequencies 19 – 89 GHz
- It is an empirical algorithm
- Leveraged Grenfell and Putkonen's (JGR 2008) spectral detection
- Added a temporal detection

Prototype algorithm – Spectral detection

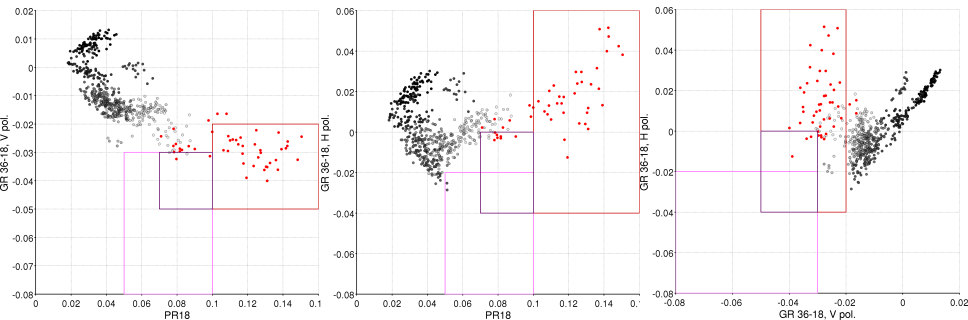
Banks Island, 2003



During 1 month before the ROS event

Prototype algorithm – Spectral detection

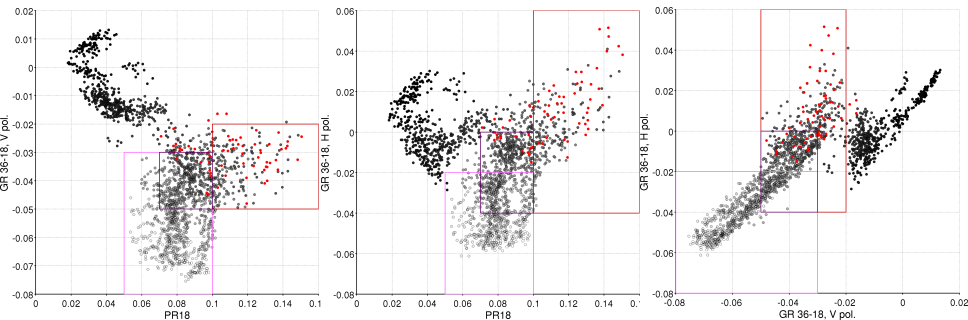
Banks Island, 2003



The day of the ROS event until 3 days after

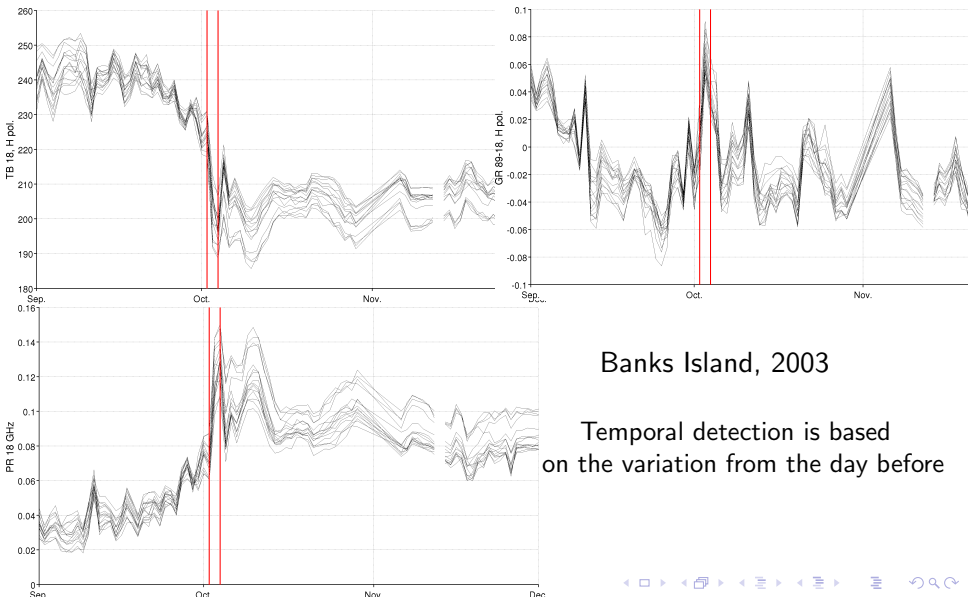
Prototype algorithm – Spectral detection

Banks Island, 2003



From 1 month before to 2 months after the event

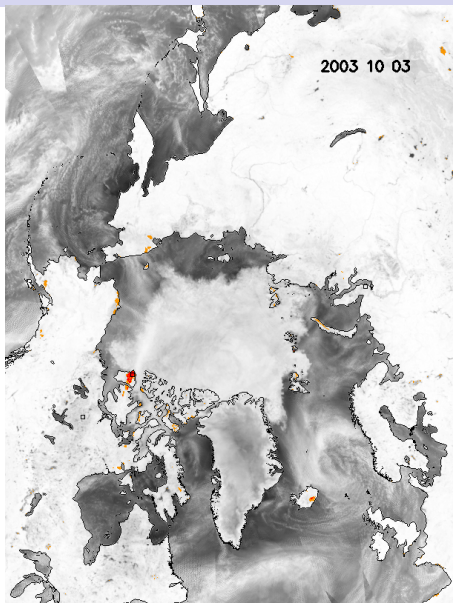
Prototype algorithm – Temporal detection



Banks Island, 2003

Temporal detection is based on the variation from the day before

Prototype algorithm – Daily detection

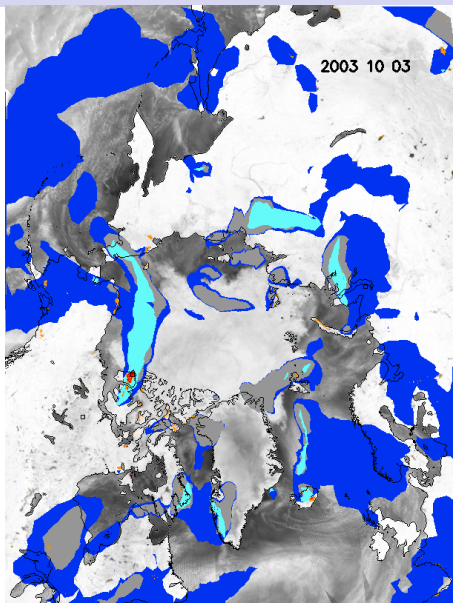


Banks Island, 2003

ROS detected with both spectral
& temporal signatures

ROS with either spectral
or temporal signatures

Prototype algorithm – Daily detection



Banks Island, 2003

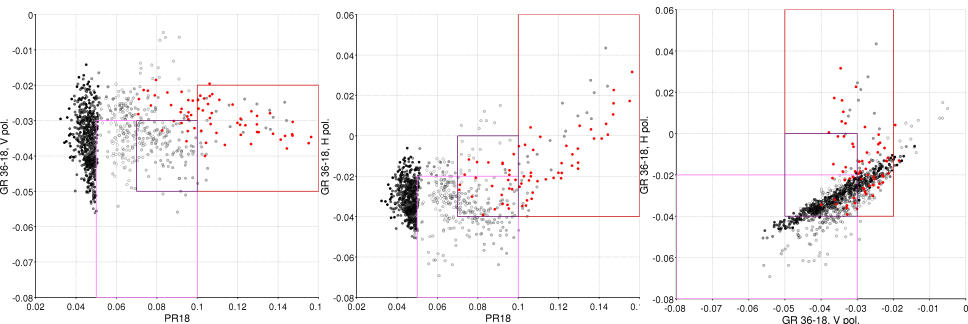
ROS detected with both spectral
& temporal signatures

ROS with either spectral
or temporal signatures

ERA-interim rainfall
ERA-interim rain in the vicinity
of sub-freezing temperatures

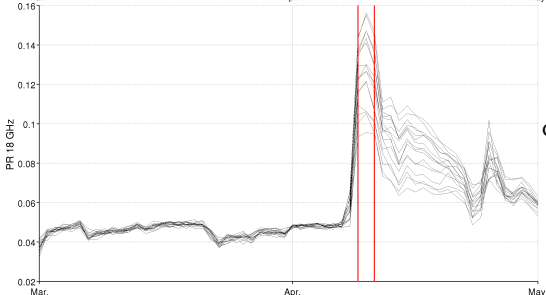
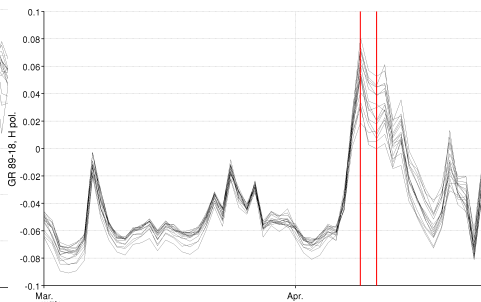
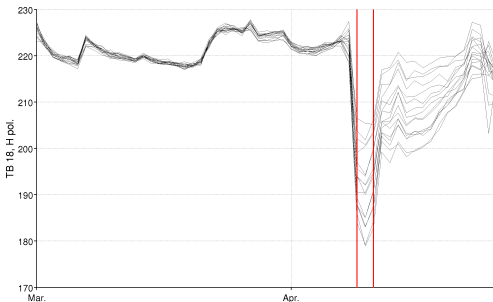
Prototype algorithm – Spectral detection

Daring Lake, 2007



Ice lens near the surface (*Rees et al., RSE 2010*)

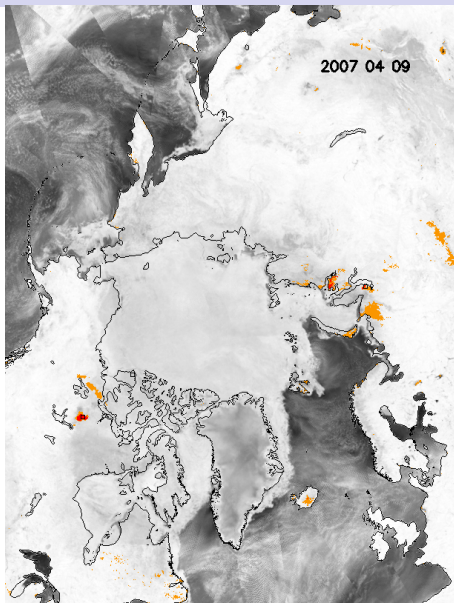
Prototype algorithm – Temporal detection



Daring Lake, 2007

Temporal detection is based on the variation from the day before

Prototype algorithm – Daily detection

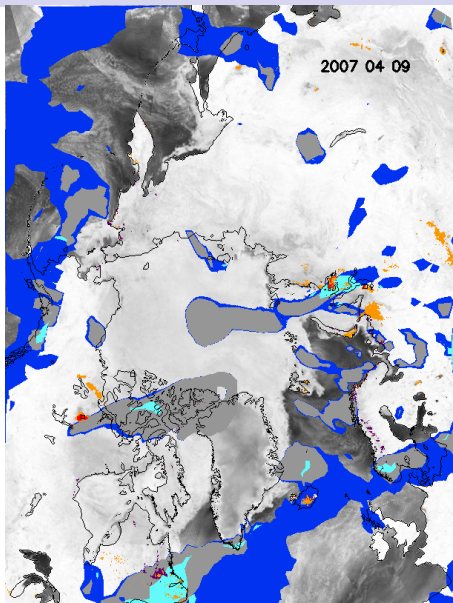


Daring Lake, 2007

ROS with both spectral
& temporal signatures

ROS with either spectral
or temporal signatures

Prototype algorithm – Daily detection



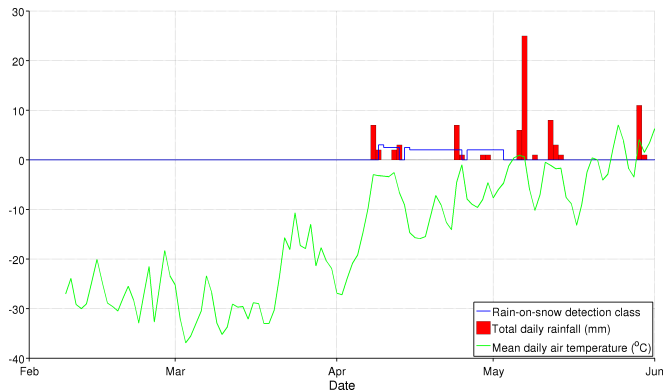
Daring Lake, 2007

ROS with both spectral
& temporal signatures

ROS with either spectral
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ERA-interim rainfall
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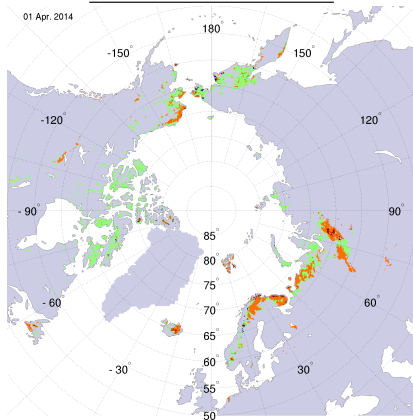
Daring Lake, weather station data



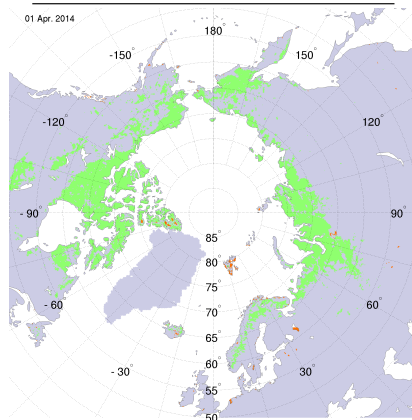
- Timely detection of the first rain-on-snow event of the season
- No false detection due to melting snow ($T_{\text{air}} > 0^{\circ}\text{C}$)

Algorithm comparison in Spring (April 1, 2014)

Prototype algorithm



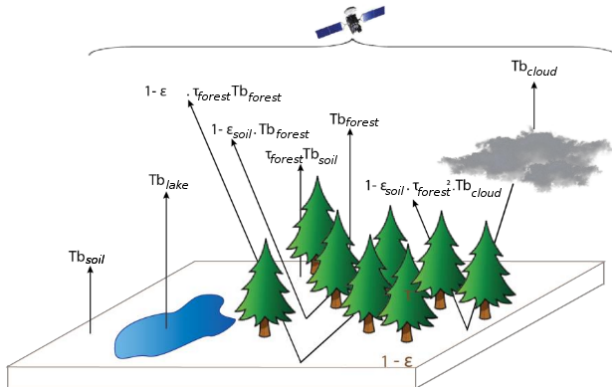
Grenfell and Putkonen (2008)



Using spectral and temporal signatures reduces spurious detections

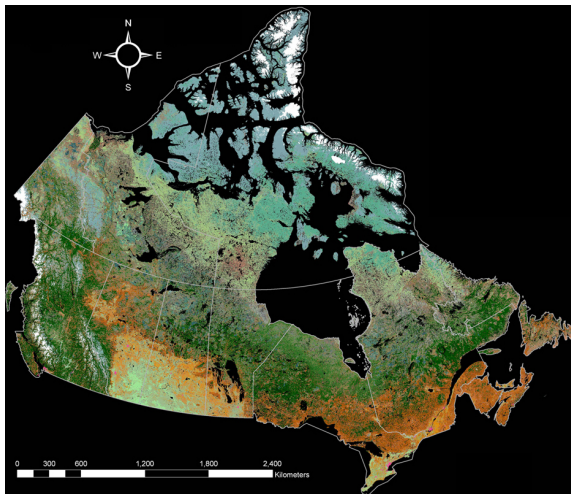
Important for a large scale application of the algorithm

Microwave radiometers have a coarse spatial resolution (5–50 km)



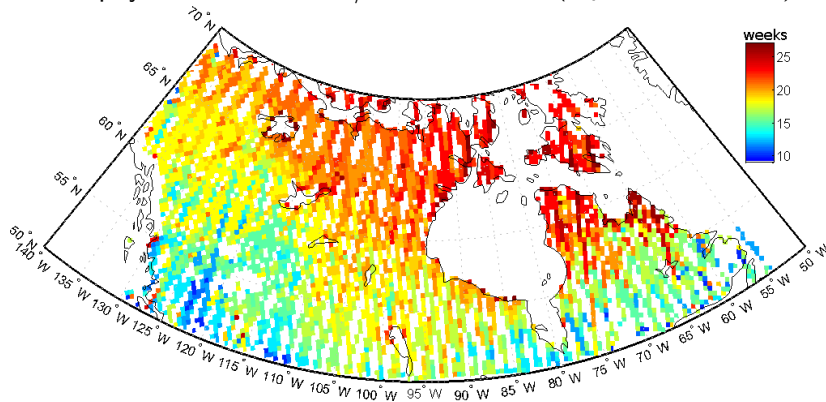
Important for a large scale application of the algorithm

Vegetation transmissivity (*Vander Jagt, RSE 2014; Langlois et al., TGRS 2011*)



Important for a large scale application of the algorithm

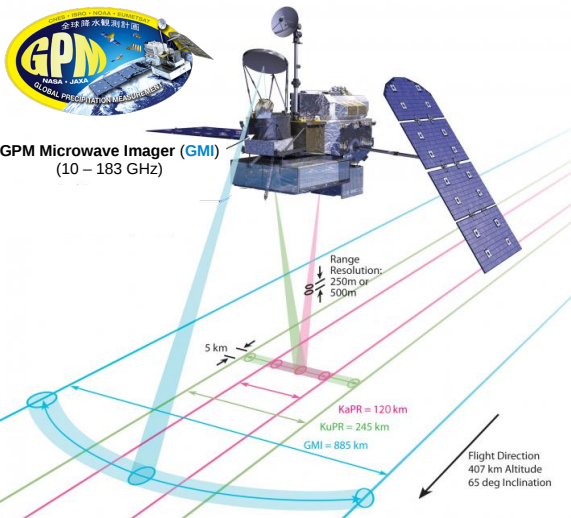
Soil physical state: freeze/thaw condition (*Roy et al., for JSTARS*)



See poster tomorrow on Aquarius products for studying the cryosphere

Global Precipitation Measurement (NASA - JAXA)

Since March 2014, GPM operates microwave radiometers & radars

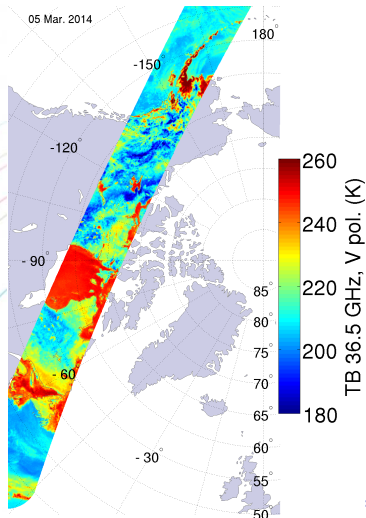
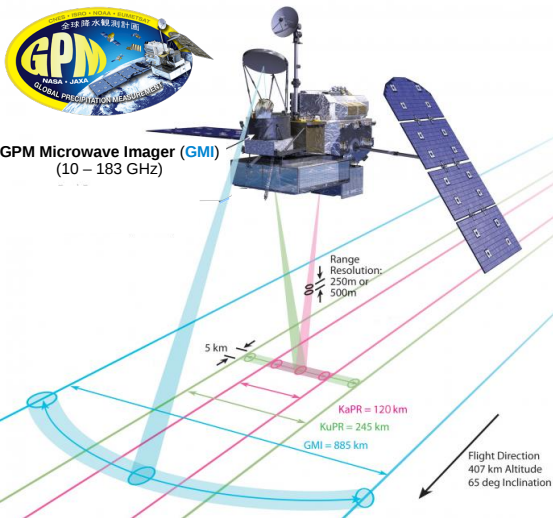


Global Precipitation Measurement (NASA - JAXA)

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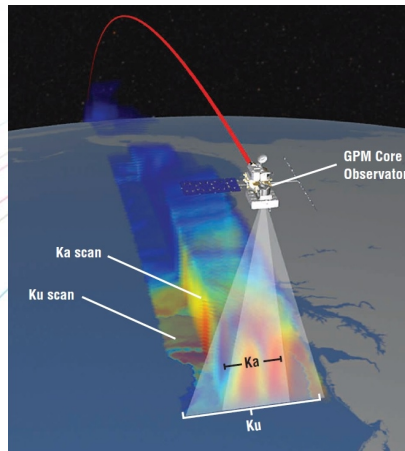
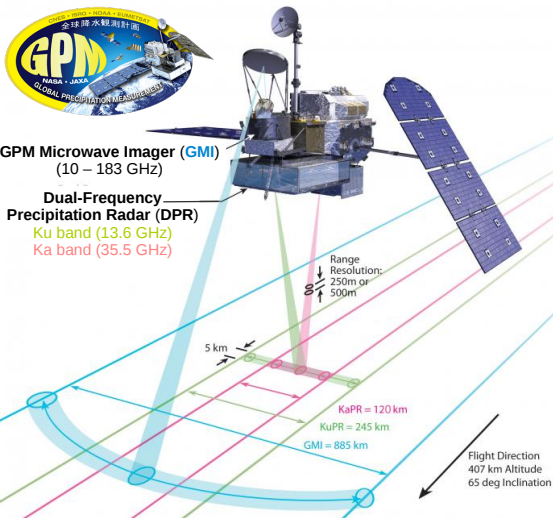


GPM Microwave Imager (GMI)
(10 – 183 GHz)



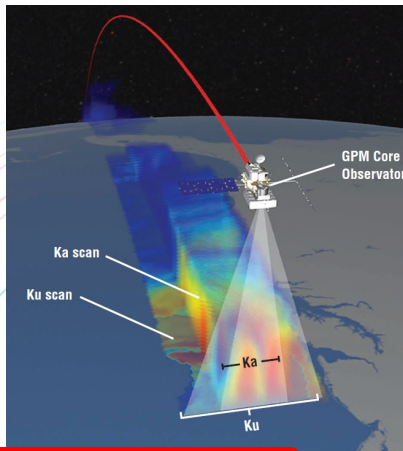
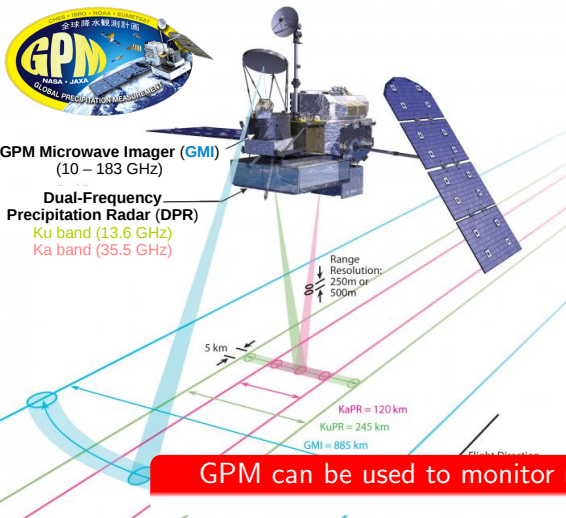
Global Precipitation Measurement (NASA - JAXA)

Since March 2014, GPM operates microwave radiometers & radars



Global Precipitation Measurement (NASA - JAXA)

Since March 2014, GPM operates microwave radiometers & radars



GPM can be used to monitor rain on snow directly

Global Precipitation Measurement (NASA - JAXA)

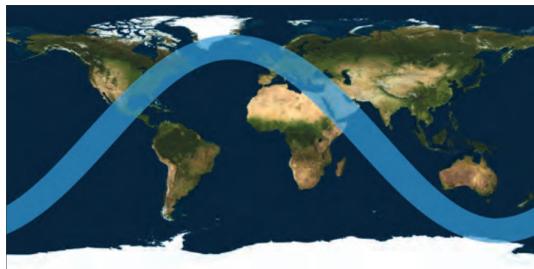
Orbit

circular

non-sun-synchronous

65° inclination

~16 orbits per day



GPM data: pmm.nasa.gov/data-access/downloads/gpm

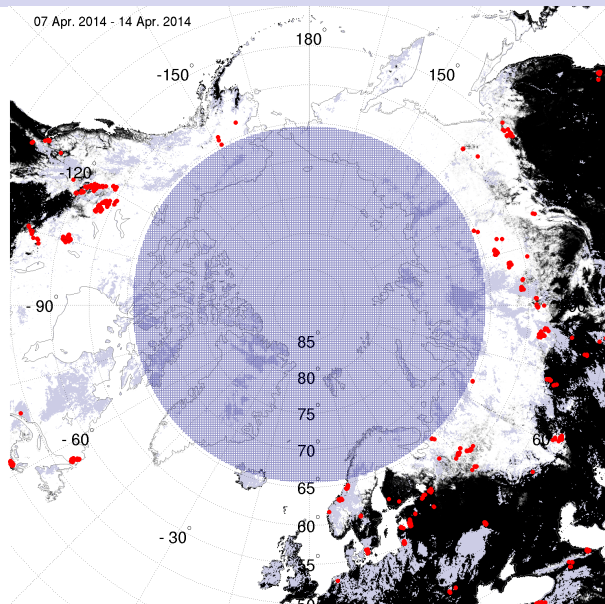
(Hou et al., BAMS 2014: *The Global Precipitation Measurement Mission*)

Level 1C products of: TB \rightsquigarrow surface state (snow/no snow)

Reflectivity \rightsquigarrow precipitation type and rate

Global Precipitation Measurement

07 Apr. 2014 - 14 Apr. 2014



● GMI+DPR ROS
MODIS snow cover extent

Looking forward to the
first complete winter of
detection

Conclusion

- Monitoring rain on snow is relevant for
 - . wintertime climate monitoring
 - . supporting climate adaptation
- A prototype algorithm was developed based on spectral signatures & temporal signatures
- It is designed to detect rain-on-snow events, especially those leading to the formation of ice layering
- GPM observations provide an outstanding source of validation

